New observation of cone flies attacking cones of *Picea obovata* and *Larix sibirica* in central Siberia

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Abstract Two species of cone flies (*Strobilomyia anthracina* and *S. svenssoni*) emerged from puparia were collected under Siberian spruce (*Picea obovata*) trees in the central part of the Krasnoyarsk region, central Siberia. Parasites of the Figitidae and Braconidae families emerged from 28.1% of the puparia, and fungal and bacterial diseases destroyed 24.8% of the puparia. Weight and length of the puparia depended on the sanitary status. Two types of cone fly eggs were observed on spruce cones. At least three species of *Strobilomyia* (*S. Infrequens, S. laricicola*, and *S. sibirica*) attacked cones of Siberian larch (*Larix sibirica*) in central Siberia.
Key words: Cone flies, Cone damage, Central Siberia

Introduction

Cone flies of genus *Strobilomyia* Michelsen (= *Lasiomma* Stein Auct. partim = *Chorthophila* Macquart = *Hylemia* Robineau-Desvoidy, Diptera: Anthomyiidae) are widespread pests damaging cones and seeds of conifers (Roques *et al* 1996). Species of this apparently monophyletic genus occur mainly in the boreal and Montana parts of the Holartic, where larval instars develop exclusively in the cones of various groups of Pinaceae except the pine species (Michelsen, 1988). A total of 19 *Strobilomyia* species were identified (Turgeon *et al* 1994; Roques *et al* 1996), most of them being related to larch, *Larix* Miller, and spruce, *Picea* A. Dietr. In the far East, a total of 8 species, such as *S. baicalensis* (Elberg), *S. infrequens* (Ackland), *S. laricicola* (Karl), *S. luteoforceps* (Fan & Fang), *S. melaniola* (Fan), *S. sibirica* Michelsen, *S. svenssoni* Michelsen, and *S.viaria* (Huckett), have been recorded from larch cones. Whiles only one species, *S. anthracina* (Czerny) was observed in spruce cones (Fan *et al* 1982, 1990; Fang 1987; Fang *et al* 1989; Kamijo 1993; Michelsen 1988; Popova and Elberg 1970; Roques *et al* 1996; Stadnistskii *et al* 1978; Sun *et al* 1994; Suwa 1971). Two additional species (*S. appalachensis* Michelsen and *S. neanthracina* Michelsen) have been recorded to attack spruce cones in North America (Michelsen 1988).

However, some gaps still exist in the species distribution. The cone fly fauna has been little studied in central Siberia. Only a few data are available from the Krasnoyarsk region, all observations of damage to larch cones referring to *S. laricicola*, taxa under which several fly species have been probably confused for a long time. Thus, *S. laricicola* was recorded from the territories of Bolshaya Murta (Nakrokhina 1983), Evenkiya (Galkin and Nadeev 1966), Khakasiya (Luchinin and Govzich 1971), and Zapadnyi Sayan (Zemkova 1965; Rozhkov 1966; Petrenko and Zemkova 1967) the whilst *S. anthracina* was observed in Evenkiya (Grebenshchikova 1966) and Bolshaya Murta (Nakrokhina 1983). Michelsen (1988) additionally identified some larch cone flies collected in the Krasnoyarsk area as *S. infrequens* and some flies from Khakasiya as *S. sibirica*. Therefore, the aim of our study was to clarify the composition of the cone fly entomofauna attacking cones of Siberian spruce, *Picea obovata* (Ledeb.), and Siberian larch, *Larix sibirica* (Ledeb.), in the Krasnoyarsk region. We also intended to measure the specific size and weight of fly puparia.

Materials and methods

Sampling of spruce cone flies

The study was carried out during 1989~1990 in the Bolshaya Murta territory of the Krasnoyarsk region. We sampled a stand where *Picea obovata* was mixed with larch, *Larix sibirica* Ledeb. In 1990, a year of large cone crop for both spruce and larch, puparia were collected directly from the soil after the maggots had left the cones to pupate in the litter. Soil units of 25 cm × 25 cm × 15 cm (e.g., 0.009 m^3) were removed under five different spruce trees on August 29~31 and September 11. One sample was collected in per geographic quadrate of each tree in the middle part of the ground projection. A total of 31 puparia were finally extracted from the 20 soil samples. The puparia were weighted, and their length was measured. They were finally put into individual tubes filled with clean sand that had been moistened with distilled water but the substrate was not moistened afterwards. The rearing tubes were closely sealed

and stored in dry cool place. The emergence of adult flies and parasites from the puparia was surveyed during the four following years. The puparia from which no insects emerged were finally dissected in 1995. In parallel, we sampled and dissected, scaled by scale, 25 attacked cones in June 1989 and 1990 in order to look for eggs and larvae.

Sampling of larch cone flies

Using the same technique as for spruce, we collected one soil sample under a *Larix sibirica* tree in Bolshaya Murta on September 11, 1990. A total of 4 puparia were extracted from that sample and reared similarly as above. Additional collections of cones of *Larix sibirica* attacked by cone flies were carried out on June 18, 1991 in a pure larch stand near the village of Chernoye Ozero located not far from the city of Shira. 50 cones were collected in a plantation (Fig. 1) on June 20, June 27 and July 11, 1992. 98 cones were collected near Sukachev Institute, downtown Krasnoyarsk (Fig. 1). The larch cone maggots were allowed to exit the cones and pupate in wet sand. Finally, we obtained 35 and 52 puparia originating from Chernoye Ozero and Krasnoyarsk, respectively.

Results and discussion

Spruce cone flies

Only five fly imagoes (3 ♂♂ and 2 ♀♀) emerged from the 31 puparia collected in Bolshaya Murta. After dissection, nine other puparia were shown including dead fly imagoes which were unable to emerge, probably because the puparium surface was too much dry. Based on the genital apparatus (Fig. 2. a, b), one of the male specimens was identified as S. anthracina whereas the two others were identified as *S. svenssoni*. The two females presented an ovipositor sclerotization quite similar to that observed in *S. anthracina* (Michelsen 1988). *S. anthracina* is distributed throughout the range of spruce in the Paleartic, from Western Europe to Japan (Michelsen 1988). In northern Asia, it is known as attacking cones of Siberian spruce, *Picea obovata*, and those of the far-eastern spruces, *P. ajanensis* Fisch., P. ghlenii (Fr. Schntidt) Mast., *P. jezoensis* (Sieb. *et al* Zucc.) Carr., and *Pinus koraiensis* Nakai (Stadnistkii *et al* 1978; Kamijo 1993; Sun et al 1994). The puparium is brown, with 5.0 mm length, and weights 8.0 mg before overwintering. All adults emerged one year after the collection of puparia. However, we could not ascertain that puparia resulted from the development of current year's larvae or were in prolonged diapause.

S. svenssoni had previously been recorded from Sweden and Mongolia where the host was suspected to be spruce (Michelsen 1988), but it was found more recently in cones of larch, *Larix gmelini* (Rupr.) Kusen. in China (Sun *et al* 1995; Roques *et al* 1996). Although imagoes emerged from the soil samples collected under spruces in the Bolshaya Murta territory, we could not ascertain the host species because spruce grew together with larch in that place. The puparium is brown, with 5.2~5.4 mm length. It weights 11.0~13.0 mg before hibernation. The adults similarly emerged the year following the puparia collection.

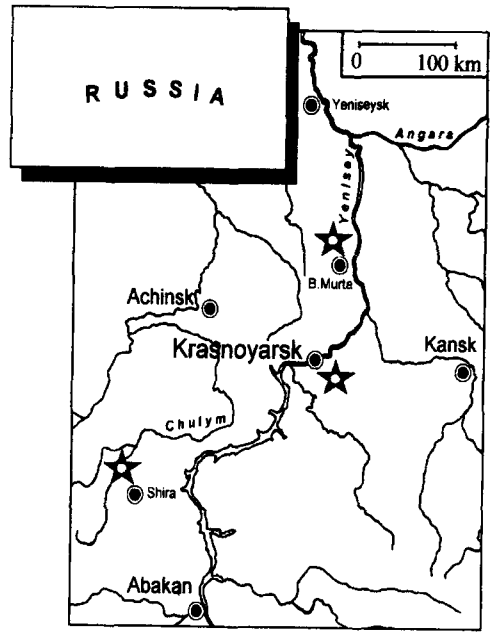

Fig. 1. Location of the experimental sites in the central Siberia (Russia) shown by stars

Two types of cone fly eggs were observed on the spruce cones collected in 1989 and in 1990. Both were elongated and whitish but they differed by the sculpture of the chorion surface. A first type had the chorion marked by a network of hexagonal cells arranged in transverse rows, and a length of 1.7± 0.1 mm. Such eggs were found inserted between scales very close to the insertion of the scale on the cone axis. Then, the larvae were observed to spiral round the axis. A second type of egg presented a smooth chorion surface and a smaller length in (1.5±0.1) mm. Such eggs were found on the inner side of scales close to the margin, but also occasionally on the cone surface the corresponding larvae left the cones for pupation later than the former ones. The second type of egg resembles that of *S. anthracina* although Brockerhoff (1994) observed it had a larger length (1.42 ~ 1.99 mm, with an average of 1.64 mm and a width of 0.57 mm) in the European specimens. The first type of egg did not fit the description of that of *S. svenssoni*, that has been detailed in China (Sun *et al*

1996). The Chinese eggs are much small (1.18 mm length on the average) and their chorion is marked with longitudinal lines of funnel-like prominence.

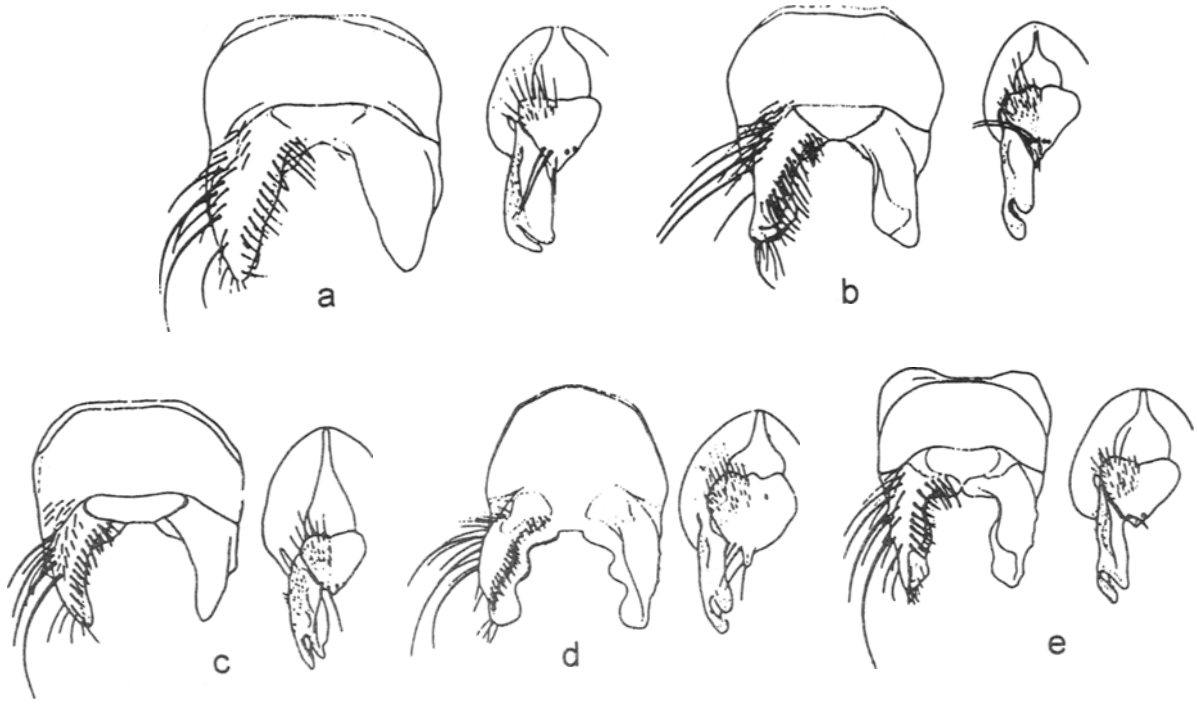

Fig. 2. Cercal plate and surstily of males of *Strobilomyia* species observed in central Siberia
a.-- *S. anthracina*; b.--*S. svenssoni*; c.-- *S. sibirica*; d.-- *S. laricicola*; e.-- *S. infrequens* (modified after Michelsen in 1988).

The relative proportion of each egg type varied with the year. In 1989, the first type of egg represented 42.7% of the total (82 eggs) but only 33.3% of the total in 1990 (10 eggs). Conversely, the second type represented 57.3% in 1989 and 66.7% in 1990. The position of eggs on the cone also varied, apparently in relation to the annual size of the spruce cone crop. In 1989, a year of poor crop, both types of eggs was laid at any place on the cone, from basis to apex. In 1990, when the cone crop was large, we found one egg per cone as a rule, and eggs were concentrated in the basal and middle part of the cones. In northern Italy, Brockerhoff (1994) observed that 67% of the eggs of *S. anthracina* was laid in the basal part and 23% in the middle part of the cones during a year of poor crop.

Parasitoids of spruce cone flies

A total of 10 imagoes of parasitoids emerged from the puparia three years after they had been collected. By contrast to the flies, all the imagoes of parasitoids emerged successfully or at least cut the puparium. The parasitoids have well-developed mandibles, which enable them to cut the puparium envelop even when it is dry.

We concluded that soil moisture was probably more important for the successful development of cone flies than for that of the related parasitoids. Thus, we evaluated the percentage of parasitized puparia is 28.1. During a survey of *S. anthracina* in western and central Europe, Brockerhoff (1994) found endoparasitoids in only seven over 27 cone fly samples, and the parasitism rate ranged from 1% to 25% in the parasitized areas. In Bolshaya Murta, endoparasitoids included an unidentified Figitidae (18.8% of the puparia) and a Braconidae, *Phaenocarpa* sp. (9.3% of the puparia). Seven species of endoparasitoids have been yet recorded from *S. anthracina*. Among them there are four species of Figitidae (*Sarothrus abietis* Belizin and *Sarothrus* sp. in the areas of Leningrad and Novgorod in Russia, Stadnitskiy *et al* 1978; *S. areolatus* Hartig in the Alps, Brockerhoff 1994; and *Melanips* sp. in Finland) and three species of Ichneumonidae of the genus *Attractodes* (*A. scutellatus* Hellèn in Finland, Kangas and Leskinnen 1943; *A. foveolatus* Grav. and *Attractodes* aff. *liogaster* Thomson in Russia, Stadnitskiy *et al* 1978). *Phaenocarpa* sp. was also observed to parasitize spruce cone flies in the region of Irkustk (Golutvina 1973). However, our study only dealt with the parasitization of puparia, and it is likely that other parasitoids, either egg parasitoids or larval parasitoids, as well as predators affect spruce cone

flies in central Siberia. In Europe, Brockerhoff (1994) recorded *Trichogramma* sp. (Hymenoptera: Trichogrammatidae) and *Scambus* sp., probably *strobilorum* Ratz. (Hymenoptera: Ichneumonidae), as an egg parasitoid and a larval ectoparasitoid, respectively, whereas Kangas and Leskinnen (1943) observed *Earomyia schystopyga* Collin (Diptera: Lonchaeidae) to be a predator. In addition, seven pupae (24.8%) were dead because of fungal or bacterial diseases. The puparium mortality due to factors other than parasitoids was much more important than that observed by Brockerhoff in Switzerland and Italy (3.2 to 7.5%). The parasitized puparia were significantly smaller and lighter than the non-parasitized ones (Table 1). The puparia killed by pathogens were as long as the other types but significantly lighter (Table 1). The size and weight of puparia before overwintering can thus be used for an early forecast of the sanitary status of cone flies.

Table 1. Length and weight of puparia of spruce cone flies collected in Bolshaya Murta, with regard to the sanitary status before overwintering

Puparium type	Length ± S. E. / mm	CV %	Weight ± S. E. / mg	CV %
Sound	5.67±0.39 a*	25.5	11.3±0.16 a	17.0
Parasitized puparia	4.89±0.16 ab	9.6	5.29±0.43 b	24.3
Damaged by fungi	5.37±0.63 a	20.4	< 2.3 c	

Notes: * --Values of the same column followed by the same letter are not significantly different at P= 0.05 (Mann-Witney U-test)

Larch cone flies

Only one male fly emerged from 4 puparia sampled in Bolshaya Murta (i.e. 75% of mortality), and it was identified as *S. sibirica* (Fig. 2. c). The more number of adult flies, including 3 species (*S. infrequens* in Fig. 2. e, *S. laricicola* in Fig. 2. d, and *S. sibirica*) emerged from two samples collected at Chernoye Ozero (22 adults over 35 puparia, i.e. 37.1% of mortality) and Krasnoyarsk (27 adults over 52 puparia, i.e. 48% of mortality in Table 2).

Table 2. Adult of larch cone flies emerged from puparia in larch cones at Chernoye Ozero in 1991 and Krasnoyarsk in 1992

Species	Chernoye ozero		Krasnoyarsk					
	June 18		June 20		June 27		July 11	
	♂	♀	♂	♀	♂	♀	♂	♀
S. laricicola	2	3	1	5	3	2	4	1
S. infrequens	4	2	-	-	1	-	-	-
S. sibirica	6	5	4	1	3	2	-	-

The imagoes emerged the year after the cone collection in Chernoye Ozero and Krasnoyarsk but that of Bolshaya Murta emerged three years after the puparium collection. *S. laricicola* was dominant in Krasnoyrask (59.3% of the emergence) independently of the date of cone collection. *S. sibirica* was dominant in Chernoye Ozero (50% of the emergences). *S. infrequens* was more abundant than *S. laricicola* in Chernoye Ozero (27.2% vs. 22.7% of the emergence) but rather scarce in Krasnoyarsk (3.7%).

However, these results must be taken with care because the relative abundance of cone flies depends on both the size of the annual cone crop and the date of cone collection, the maggots of the different fly species leaving the cones at different times (Pulkinnen 1989). Usually, *S. laricicola* is the earliest species to leave the cone (Sun *et al* 1995).

These results confirmed Michelsen's identifications, and proved that at least three species of cone flies were attacking larch cones in central Siberia. Because of the limited size of the samples, it may however be possible that other cone fly species exist in the area. *S. laricicola* and *S. infrequens* have a palearctic distribution, from western Europe to the Far East but the second species has not yet been recorded from Japan (Michelsen. 1988; Roques *et al* 1996). *S. sibirica* has an eurosiberian distribution, from Scandinavia and European part of Russia to Central Siberia (Popova and Elberg 1970; Michelsen 1988; Pulkinnen 1989). The puparium of the Siberian specimens of *S. infrequens* fits the description of European specimens (Sun *et al* 1993) whereas that of *S. sibirica* fits the description of the Chinese specimens (Fan 1995). The puparium of *S. sibirica* is brown, with 5.0 mm length, and weights 9.0 mg before overwintering.

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